CLAIMS

What is claimed:

1. A method of fabricating a semiconductor device, having an interim reduced-oxygen copper-zinc (Cu-Zn) alloy thin film formed on a copper (Cu) surface by electroplating the Cu surface in a chemical solution, comprising the steps of:
providing a semiconductor substrate having a Cu surface formed in a via;
providing a chemical solution;
electroplating the Cu surface in the chemical solution, thereby forming an interim Cu-Zn alloy thin film on the Cu surface;
rinsing the interim Cu-Zn alloy thin film in a solvent;
drying the interim Cu-Zn alloy thin film under a gaseous flow;
annealing the interim Cu-Zn alloy thin film formed on the Cu surface, thereby forming an interim reduced-oxygen Cu-Zn alloy thin film;
filling the via with Cu on the interim reduced-oxygen Cu-Zn alloy thin film, thereby forming a Cu-fill;
annealing the Cu-fill, the interim reduced-oxygen Cu-Zn alloy thin film and the Cu surface;
planarizing the Cu-fill, the interim reduced-oxygen Cu-Zn alloy thin film and the Cu surface, thereby forming a dual-inlaid interconnect structure; and
completing formation of the semiconductor device.

2. A method, as recited in Claim 1,
wherein the chemical solution is nontoxic and aqueous, and
wherein the chemical solution comprises:
at least one zinc (Zn) ion source for providing a plurality of Zn ions;
at least one copper (Cu) ion source for providing a plurality of Cu ions;
at least one complexing agent for complexing the plurality of Cu ions;
at least one pH adjuster;
at least one wetting agent for stabilizing the chemical solution, all being dissolved in a volume of deionized (DI) water.

3. A method, as recited in Claim 2,
wherein the at least one zinc (Zn) ion source comprises at least one zinc salt selected from a group consisting essentially of zinc acetate ($(CH_3CO_2)_2Zn$), zinc bromide ($ZnBr_2$), zinc carbonate hydroxide ($ZnCO_3 \cdot 2Zn(OH)_2$), zinc dichloride ($ZnCl_2$), zinc citrate ($(O_2CCH_2C(OH)(CO_2)CH_2CO_2)_2Zn_3$), zinc iodide ($ZnI_2$), zinc L-lactate ($(CH_3CH(OH)CO_2)_2Zn$), zinc nitrate ($Zn(NO_3)_2$), zinc stearate ($CH_3(CH_2)_{16}CO_2)_2Zn$), zinc sulfate ($ZnSO_4$), zinc sulfide ($ZnS$), zinc sulfite ($ZnSO_3$), and their hydrates.

4. A method, as recited in Claim 2,
wherein the at least one copper (Cu) ion source comprises at least one copper salt selected from a group consisting essentially of copper(I) acetate (CH_3CO_2Cu), copper(II) acetate ($(CH_3CO_2)_2Cu$), copper(I) bromide ($CuBr$), copper(II) bromide ($CuBr_2$), copper(II) hydroxide ($Cu(OH)_2$), copper(II) hydroxide phosphate ($Cu_2(OH)PO_4$), copper(I) iodide (CuI), copper(II) nitrate ($(CuNO_3)_2$), copper(II) sulfate ($CuSO_4$), copper(I) sulfide (Cu_2S), copper(II) sulfide (CuS), copper(II) tartrate ($(CH(OH)CO_2)_2Cu$), and their hydrates.

5. A method, as recited in Claim 1,
wherein said electroplating step comprises an electroplating apparatus, and wherein said electroplating apparatus comprises:

(a) a cathode-wafer;
(b) an anode;
(c) an electroplating vessel; and
(d) a voltage source.

6. A method, as recited in Claim 5, wherein the cathode-wafer comprises the Cu surface, and wherein the anode comprises at least one material selected from a group consisting essentially of copper (Cu), a copper-platinum alloy (Cu-Pt), titanium (Ti), platinum (Pt), a titanium-platinum alloy (Ti-Pt), an anodized copper-zinc alloy (Cu-Zn, i.e., brass), a platinized titanium (Pt/Ti), and a platinized copper-zinc (Pt/Cu-Zn, i.e., platinized brass).

7. A method, as recited in Claim 1, wherein said semiconductor substrate further comprises a barrier layer formed in the via under said Cu surface, and wherein the barrier layer comprises at least one material selected from a group consisting essentially of titanium silicon nitride ($Ti_xSi_yN_z$), tantalum nitride (TaN), and tungsten nitride (W_xN_y)

8. A method, as recited in Claim 7, wherein said semiconductor substrate further comprises an underlayer formed on the barrier layer, wherein said underlayer comprises at least one material selected from a group consisting essentially of tin (Sn) and palladium (Pd), and wherein said Cu surface is formed over said barrier layer and on said underlayer.

9. A method, as recited in Claim 8, wherein said underlayer comprises a thickness range of approximately 15 Å to approximately 50 Å, wherein said barrier layer comprises a thickness range of approximately 10 Å to approximately 30 Å, wherein said Cu surface comprises a thickness range of approximately 30 Å to approximately 100 Å, and wherein said interim Cu-Zn alloy thin film comprises a thickness range of approximately 100 Å to approximately 300 Å.

10. A method, as recited in Claim 1, wherein the annealing steps are performed in a temperature range of approximately 150°C to approximately 450°C, and wherein the annealing steps are performed for a duration range of approximately 0.5 minutes to approximately 60 minutes.

11. A semiconductor device, having an interim reduced-oxygen copper-zinc (Cu-Zn) alloy thin film formed on a copper (Cu) surface by electroplating the Cu surface in a chemical solution, fabricated by a method comprising the steps of:
providing a semiconductor substrate having a Cu surface formed in a via;
providing a chemical solution;
electroplating the Cu surface in the chemical solution, thereby forming an interim Cu-Zn alloy thin film on the Cu surface;
rinsing the interim Cu-Zn alloy thin film in a solvent;
drying the interim Cu-Zn alloy thin film under a gaseous flow;
annealing the interim Cu-Zn alloy thin film formed on the Cu surface, thereby forming an interim reduced-oxygen Cu-Zn alloy thin film;
filling the via with Cu on the interim reduced-oxygen Cu-Zn alloy thin film, thereby forming a Cu-fill;
annealing the Cu-fill, the interim reduced-oxygen Cu-Zn alloy thin film and the Cu surface;
planarizing the Cu-fill, the interim reduced-oxygen Cu-Zn alloy thin film and the Cu surface, thereby forming a dual-inlaid interconnect structure; and
completing formation of the semiconductor device.

12. A device, as recited in Claim 11, wherein the chemical solution is nontoxic and aqueous, and wherein the chemical solution comprises:

at least one zinc (Zn) ion source for providing a plurality of Zn ions;
at least one copper (Cu) ion source for providing a plurality of Cu ions;
at least one complexing agent for complexing the plurality of Cu ions;
at least one pH adjuster;
at least one wetting agent for stabilizing the chemical solution, all being dissolved in a volume of deionized (DI) water.

13. A device, as recited in Claim 12, wherein the at least one zinc (Zn) ion source comprises at least one zinc salt selected from a group consisting essentially of zinc acetate ($(CH_3CO_2)_2Zn$), zinc bromide ($ZnBr_2$), zinc carbonate hydroxide ($ZnCO_3 \cdot 2Zn(OH)_2$), zinc dichloride ($ZnCl_2$), zinc citrate ($(O_2CCH_2C(OH)(CO_2)CH_2CO_2)_2Zn_3$), zinc iodide ($ZnI_2$), zinc L-lactate ($(CH_3CH(OH)CO_2)_2Zn$), zinc nitrate ($Zn(NO_3)_2$), zinc stearate ($CH_3(CH_2)_{16}CO_2)_2Zn$), zinc sulfate ($ZnSO_4$), zinc sulfide ($ZnS$), zinc sulfite ($ZnSO_3$), and their hydrates.

14. A device, as recited in Claim 12, wherein the at least one copper (Cu) ion source comprises at least one copper salt selected from a group consisting essentially of copper(I) acetate (CH_3CO_2Cu), copper(II) acetate ($(CH_3CO_2)_2Cu$), copper(I) bromide ($CuBr$), copper(II) bromide ($CuBr_2$), copper(II) hydroxide ($Cu(OH)_2$), copper(II) hydroxide phosphate ($Cu_2(OH)PO_4$), copper(I) iodide (CuI), copper(II) nitrate hydrate ($(CuNO_3)_2$), copper(II) sulfate ($CuSO_4$), copper(I) sulfide (Cu_2S), copper(II) sulfide (CuS), copper(II) tartrate ($(CH(OH)CO_2)_2Cu$), and their hydrates.

15. A device, as recited in Claim 11,
wherein said electroplating step comprises using an electroplating apparatus, and wherein said electroplating apparatus comprises:
(a) a cathode-wafer;
(b) an anode;
(c) an electroplating vessel; and
(d) a voltage source.

16. A device, as recited in Claim 15,
wherein the cathode-wafer comprises the Cu surface, and
wherein the anode comprises at least one material selected from a group consisting essentially of copper (Cu), a copper-platinum alloy (Cu-Pt), titanium (Ti), platinum (Pt), a titanium-platinum alloy (Ti-Pt), anodized copper-zinc alloy (Cu-Zn, i.e., brass), and platinized titanium (Pt/Ti), and platinized copper-zinc (Pt/Cu-Zn, i.e., platinized brass).

17. A device, as recited in Claim 11,
wherein said semiconductor substrate further comprises a barrier layer formed in the via under said Cu surface, and
wherein the barrier layer comprises at least one material selected from a group consisting essentially of titanium silicon nitride ($Ti_xSi_yN_z$), tantalum nitride (TaN), and tungsten nitride (W_xN_y)

18. A device, as recited in Claim 17,
wherein said semiconductor substrate further comprises an underlayer formed on the barrier layer,
wherein said underlayer comprises at least one material selected from a group consisting essentially of tin (Sn) and palladium (Pd), and
wherein said Cu surface is formed over said barrier layer and on said underlayer.

19. A device, as recited in Claim 18,
wherein said underlayer comprises a thickness range of approximately 15 Å to approximately 50 Å,
wherein said barrier layer comprises a thickness range of approximately 10 Å to approximately 30 Å,
wherein said Cu surface comprises a thickness range of approximately 30 Å to approximately 100 Å, and
wherein said interim Cu-Zn alloy thin film comprises a thickness range of approximately 100 Å to approximately 300 Å.

20. A semiconductor device, having an interim reduced-oxygen copper-zinc alloy (Cu-Zn) thin film formed on a copper (Cu) surface, comprising:
a semiconductor substrate having a via; and
a dual-inlaid interconnect structure formed and disposed in said via, said interconnect structure comprising:
at least one Cu surface formed in said via;
an interim reduced-oxygen Cu-Zn alloy thin film formed and disposed on the at least one Cu surface; and
a Cu-fill formed and disposed on said interim reduced-oxygen Cu-Zn alloy thin film.